A GREEK CONCEPTION OF THE CONSTITUTION OF MATTER

By Joseph B. Pike
University of Minnesota

The following striking statement of Sir Henry Maine stands as a text to Book I of Gomperz' *Greek Thinkers:* "To one small people it was given to create the principle of progress. That people was the Greek. Except the blind forces of nature, nothing moves in this world which is not Greek in its origin." The more one studies and thinks with this text in mind the greater the marvel grows, for the Greek influence really does extend into fields which, at first thought, it would not seem to have reached. Indeed, in the course of these pages it will be apparent that though Greece of course had nothing to do with the movement of the blind forces of nature, she had a great deal to do with the explanation of their causes.

The theories of the early Greek philosophers as to the basis of the physical universe, important as they are in the history of human thought, possess at the present time for the most part merely an antiquarian interest. There is, however, one rather notable exception, the Greek atomic theory. This theory is a most striking exemplification of the intuitive faculty of the Greek mind. It was not the result of experiment or observation or conclusions drawn therefrom, but the result of the most abstract metaphysical concepts, and yet in its main outline the hypothesis is indispensable to science at the present time. Our colleagues in physics will tell us that recent discoveries with regard to radio-active elements, far from overthrowing the atomic theory, have but made its acceptance the more necessary.

Modern physics postulates that all substances, solids as well as liquids and gases, are composed of minute particles called molecules and that these molecules are in very rapid motion. When the term "molecule" is used exactly, it will indicate the smallest portion

of matter which retains its identity as a particular substance. Any further division would destroy the identity of the substance and reduce it to the atom. In the case of the chemical elements the atom and the molecule may be identical.

Recent investigations and discoveries have proved that enormous quantities of energy are locked up in the atoms of all substances. One widely accepted theory would make the atom consist of a nucleus of positive charges of electricity around which the negative electrons rotate rapidly. The physicist has before him the fascinating problem of endeavoring to unlock this store of atomic energy in order to turn it to the uses of man. The atom, therefore, is a live and vital thing, and it may be of some interest to consider the ancient speculations with regard to its nature and behavior.

We shall omit a discussion of the early Greek atomists before Epicurus and merely remark by way of preface that Leucippus, the father of atomists, owed much to the speculations of the Eleatic school, and that Democritus, the immediate precursor of Epicurus, did most for the development of that theory which Epicurus somewhat modified and adopted as the physical basis of his system of philosophy. We proceed directly to a consideration of this theory as taught by Epicurus and transmitted to us by Lucretius.

It is true that Lucretius did not, so far as we know, make a single contribution to the doctrine as formulated by Epicurus, but our debt to him is great because our understanding of the theory is due almost exclusively to his clear and striking exposition. How great this debt is, may be inferred by a comparison of the bare facts of the physics of the system, as outlined by Epicurus himself in a letter preserved by Diogenes Laërtius, with the vivid account of Lucretius.

We first give a résumé[1] of the theory and then consider how this tallies with known facts and theories at the present time.

There must be, argued Epicurus, as the basis of all existing things an unchanging and everlasting substance. This substance Epicurus calls atoms. Nothing is ever destroyed, but things are

[1] Munro's outline is followed for the most part.

resolved into their primal atoms. The sum-total of matter in the universe remains constant. Atoms are invisible; they never have been and never can be seen. Objects are formed by a combination of atoms and have in them void also, the second element in nature. Everything in nature may be reduced to these two terms, body and void, that in which body moves. Neither sense nor reason can grasp any third class. All qualities are either inseparable properties or are accidents of matter or void. Time exists not by itself; from the actions that go on, follows the feeling of past, present, and future. The deeds done at the siege of Troy, for example, did not exist by themselves, but were mere accidents of the men there or the places there.

Atoms are absolutely solid, having no mixture of void in them. As there is no object in nature perfectly solid, reason alone assigns this characteristic to atoms. First beginnings are of solid singleness—*solida simplicitate*, as Lucretius puts it—that is, with no mixture of void and absolutely indivisible. Postulate solid atoms, and soft bodies may be explained by the introduction of void into their composition. With soft atoms the existence of hard things cannot be understood. The absolutely solid and indivisible atoms have, nevertheless, theoretical parts, *minimae partes*—least parts, they are called. These parts have no existence apart from the atom. The atom, therefore, has not been formed from a union of these parts, but it has existed in it unchanged from eternity. The universe is absolutely limitless; this being so, space and void are infinite. So, too, the sum of things and matter is infinite; for space being infinite, if matter were finite, nothing in being could exist a moment, or rather, nothing could ever have been brought into a state of existence, for it is only by an infinite supply of matter that this earth and heaven can be maintained. As mere blind chance, not Providence, has arranged out of the atoms this and other worlds, these atoms never could have *thus* combined, had there not been an infinite supply of them. Atoms move ceaselessly through void of their own inherent motion or it may be after collision with others. Atoms of intricate shape after collision may form a close union and help compose hard bodies; others rebound to greater intervals and keep oscillating through these

greater intervals and thus form softer bodies. Lucretius uses the striking illustration of the motes of dust in a sunbeam to illustrate his conception of what must be the motion of atoms. Next considering the motes of dust, as they really are—objects formed by the combination of atoms—he argues that the single atoms have combined into very minute objects to which are imparted the inherent motion of the atoms. Then larger combinations are formed until we have the visible mote of dust with motion imparted by the atom, rising into the field of perception.

The motion of atoms is inconceivably swift. The natural original movement of atoms is downward. At quite uncertain times and places atoms swerve an imperceptible degree. Were it not for this swerve the continual fall of atoms in perpendicular lines through the infinite void would result in nothing. As a matter of fact they would to all intents and purposes be standing still. The theory of swerve is needed to bring them into collision and admit the creation of the world. This device is also required to break the eternal sequence of cause and effect and admit the principle of free will.

The sum-total of the universe was never more or less than it is now, and the motion which atoms now have they always have had and always will have. Though atoms are in constant motion, yet the whole universe appears to be at rest, because the atoms which compose it are far beneath the ken of our senses.

Atoms are of various shapes. The difference in shape of atoms is the reason for the variation of individuals of a given species. This is also the cause of the difference in volatility of some substances. Lightning can pass where ordinary fire cannot, because its atoms are finer; light passes through horn but water does not; wine runs easily, oil slowly, through a strainer. The different shapes of the atoms which compose the different substances are the cause of these phenomena.

The different sensations are also caused by the difference in the shape of the atoms. Honey is sweet, wormwood bitter. The former is composed of smooth, the latter of jagged, atoms.

The number of shapes of atoms is finite though very great; the number of atoms of each shape infinite. The alphabet which

we use serves as an illustration. There is a definite number of different letters, but an inexhaustible supply of any particular letter.

Atoms have no color and in fact none of the secondary qualities, such as heat, cold, sound, flavor, smell. A neutral element is needed to form the basis of all created things.

Atoms are without sensibility. All things that have sense come from insensible atoms as a result of the manner in which certain atoms of very subtle nature combine and as a result of the kind of motion resulting from this combination.

Since space is unlimited and atoms infinite in number, it is not reasonable to suppose that this world would be the only world, since it has been formed by a chance combination of atoms; there are in other parts of space like combinations of atoms or other worlds and, what is more, inhabitated worlds.

As everything in nature grows by gradual steps, by taking unto itself that which it needs until it reaches the acme of its growth and thereafter begins to wane, and finally disappears, so, too, this world of ours will dissolve into its primal elements and the process of rebuilding will begin again and so on *ad infinitum*.

The particular *application* of this theory of atoms which we have just sketched contains little that is true and much that is absurd. An examination of the *doctrines* themselves, however, will reveal the somewhat surprising fact that the main outline of this ancient theory of the constitution of matter is substantially correct even in the light of the most recent experiments.

The statement that nothing is begotten from nothing and that nothing happens without a material cause must be accepted as applied to the material world in order that scientific knowledge may exist at all.

Nothing is ever annihilated, but is resolved into its constituent parts. This and the previous statement affirm the constancy of the total quantity of matter—a conception common enough now, but one for which antiquity had not yet the support of scientific proof. The conclusion, as usual, was reached by analogy. There was no proof of the destruction of matter. Change, however, is ever before the eyes. What appears to be destruction is simply change.

For the doctrine of void in things two proofs are adduced. If the universe were packed solid with matter no motion would be possible. This is not so, as we might have re-entering motion and there need be no vacuum. The other proof that the varying density of bodies is only to be explained by the admixture of void is the accepted theory for *ponderable* bodies today. Modern physics asserts, however, that what Lucretius calls void is filled with an imponderable substance called ether. Substitute hypothetical ether for void, and the ancient deduction as to the density of bodies is correct.

Atoms are hard and they are absolutely solid. This is incorrect. Even within our own recollection, however, the atom was described as hard, and we well remember picturing it to ourselves as a minute white billiard ball. Modern physics postulates a soft atom and attributes the hardness of things to the rapid motion of the soft atom.

The reason for the contradictory hypothesis of least parts was doubtless due to the fact that size, shape, and weight were attributed to atoms. Atoms, therefore, have extension, hence parts, and how can that which has parts be indivisible? This theory is of course incorrect. In connection with it, however, one naturally thinks of the electrons of the modern atom.

Nothing exists but matter and void. No third element can be imagined. It is argued that properties and accidents are not entities distinct from matter. This is true, but it does not prove that nothing exists but matter and void.

An attempt is made to show that every fact in the world can be explained by the properties of matter and that matter possesses very few simple properties. This proposition, if restricted to physical facts, is still held as true.

The contention that there must be some unalterable basis of matter, else all things would have been destroyed long ago, seems as sound today as it was in the days of Leucippus.

The proposition that the difference between all bodies is accounted for by the different arrangement and motion of atoms is sound. That is, matter is conceived as formed by atoms which are in constant motion. This idea so contrary to the evidence of

the senses, upon which Epicureanism based all knowledge, is the most striking example of the intuitive quality of the Greek mind; for in the light of modern investigation it has been proved to be perfectly true.

Some writers believe that Lucretius assumes his atoms to be elastic though perfectly solid. It is of course impossible for perfectly solid bodies to be elastic, hence they could not rebound on striking one another. Is it not more reasonable to suppose that Lucretius was ignorant of the fact that perfectly solid bodies could not rebound?

The behavior of the ancient atom after collision is quite in accord with that of its modern descendant, and a chemist or physicist will use terms similar to those of Lucretius in speaking of the collision, deflection, and bombardment of atoms or molecules. He will also speak just as Lucretius does of the oscillation of atoms in more or less dense bodies through greater or less intervals.

Atoms move straight down through void if they do not collide. This is incorrect. Lucretius failed to realize that there is no up or down in infinite space. He speaks of this motion doubtless as relative to the earth. It may be remarked that the difficulty that there is no up or down in infinite space seemed to trouble none of the early atomists who preceded Epicurus. The modern atom is subjected to the influence of the universal law of gravitation and its inherent motion will be similar to the motion of a planetary system. The tremendous velocity of the Epicurean atom receives the support of the exact measurements of the velocity of certain atoms by modern physicists.

The theory of the swerve of atoms has exposed Epicurus to much ridicule, both in ancient and in modern times. Democritus taught that in their fall through void the lighter atoms were overtaken by the heavier and the necessary collision occurred. Aristotle quite naturally objected that such could not be the case since atoms of whatever weight would, in void, fall with the same rapidity. Epicurus, accepting Aristotle's objection, formulated the theory of the swerve of atoms. This then was a very simple method of explaining creation and free will in man. Having ruled out of the universe everything but matter and void and yet believing

in free will, Epicurus boldly endowed his atom with free will, exercised, it seems to us, not constantly but, in Lucretius' words, at quite uncertain times. Guyau, the keenest of the interpreters of Epicurean ethics, claims that this spontaneity is ever inherent in the Epicurean atom. We cannot see that this follows from anything that the ancient authorities say of the system.

Lucretius, in stating that the swerve is so minute that it may not be called oblique motion, is following a common practice of materialists in making a difficulty as remote as possible and then disregarding it.

It has been suggested that had Epicurus had but a part of the geometrical knowledge of his contemporary Euclid, and that conception of cosmography which many men then living had, he might have discovered the laws of universal gravitation and not only the laws but—what was the despair of Newton—its mechanical cause.[1]

In the statement that the sum-total of the universe was never more or less than it is now and that the motion which atoms now have they always have had and always will have, we find an anticipation of the doctrine of the conservation of energy.

In connection with the discussion of the shapes of atoms Lucretius speaks of the different rates of motion of the atoms, e.g., of a sluggish and a volatile fluid. As he believes that the rate of motion of atoms is constant, for he implies, we think, that the atoms even when they form a mass of iron or stone move as swiftly as they do when streaming through space, we encounter a difficulty. This difficulty or contradiction is due to the failure of Lucretius to distinguish between the molecule and the atom. Had he spoken of a molecule of these fluids, all would be clear. He nowhere, however, so far as we can see, makes this distinction. Giusanni, Lucretius' well-known Italian commentator, claims that he does, basing the claim upon the logic of the statement we are now discussing. The argument does not seem convincing. We detect rather a fault in reasoning on the part of Lucretius. Whether he has correctly interpreted Epicurus or has misunderstood him is not clear. The fact, therefore, that the Lucretian atom had to serve the purpose of the molecule as well, will help explain the conception

[1] "The Atomic Theory of Lucretius," *British Quarterly Review*, October, 1875.

of atoms of different shapes—smooth, jagged, hooked, etc. Crude as this conception appears, it will be remembered that the conceptions of chemical affinity which have replaced it are equally inadequate to their task and exist as mere conveniences of expression. If Lucretius implies, as we think he does—though we are not absolutely certain—that the motion of atoms in combination is constant, he is not supported by modern investigation. The rate of motion of the molecule or atom of hydrogen has been calculated at sixty-nine miles a minute, that of oxygen something like a fourth less.

Lucretius, in speaking of that combination of insensible atoms which produce sense, clearly indicates that he views life as a mode of motion of the atoms. Disturb this mode and we have unconsciousness; break it up and death ensues. We really know of no more satisfactory explanation of the phenomenon of death at the present time.

As stated before, the specific application of this theory of the constitution of matter contains little that is true and much that is absurd. The outline of the process of creation and of development on earth contains, however, some rather startling anticipations of the future.

At first nothing that now is, was to be seen—sun, stars, earth, sea, or heaven—but a strange chaotic jumble of atoms unable to combine; gradually the different parts of the world began to separate. The heavy particles of earth collected in the midst and squeezed out the lighter atoms of the other parts of the world; ether with its fires first burst forth and collecting on high formed the outmost sphere of the world; this is what Lucretius designates by the impressive phrase *flammantia moenia mundi*, "the flaming walls of the world." Between this sphere of ether and the earth, the rudiments of sun, moon, and stars took up their positions; the earth, rid of these lighter particles, sank down still more, where the bed of ocean is, and these depressions were flooded with salt water. The more the earth was beaten upon by the heat of the ether and the sun, the more it was condensed, and thus the ocean was increased by particles of moisture squeezed out of it and by the heavens by elements of fire which flew off from it. Thus the earth

sank to the bottom, and sea, air, and ether were left separate—ether above all gliding on its even way and mixing with none of the lower elements. This account of creation in its broad outlines is surprisingly similar to the nebular hypothesis of Laplace.

We need not follow Lucretius in his theories of the various phenomena of nature, for many of them are grotesque in the extreme and many opposed to correct views which were held even at that time. Among these may be cited his rejection of the theory of gravitation and the antipodes. He will often suggest several possible explanations of a phenomenon, stating that any one may be true and that it is a matter of indifference which is accepted. This unscientific procedure, typical of the attitude of the Epicurean school, is due to the fact that, though the system emphasized the importance of physics, as the ancient philosophers called it, the main interest of the sect was in the branch called ethics. As soon as Lucretius had established his thesis that the soul of man was material in structure, he was rather indifferent as to the strict application of the theory of atoms to the other facts of nature.

The theory of the survival of the fittest and the account of the growth of civilization are powerfully presented and in the main along correct lines, as follows. Many races of regularly organized creatures must have died off because they lacked some natural power by which to protect themselves; they fell a prey to others and disappeared, unable to endure the struggle for existence. Primitive man was much hardier then than now and lived like the beast in the field; ignorant of tillage, he fed on what the earth supplied of itself, acorns and berries, and drank of the running waters; he was without fire or clothes or home, without law, government, or marriage; he slept on the ground, not fearing the dark to which he had been used from childhood; his fear was the fear of savage beasts. Next the use of huts and skins and fire softened his body; marriage and the ties of family, his temper. Neighbors agreed not to injure each other and made treaties of friendship and alliance, which mostly they observed though not always. This last statement is interesting—that even before men had developed the faculty of speech they agreed by means of signs to live in peace with one another. That is, a mutual agreement to obey laws for

the common interest is the principle on which the Epicurean holds society to be based. In this doctrine Epicurus anticipated by many centuries the teaching of Rousseau.

Nature and need prompted men to the use of speech; lightning first gave fire to men; cooking they learned from the effects of the sun's rays, which they saw softening and ripening things. Every day men of genius invented improved methods of life, cities were built, lands and cattle allotted, at first according to merit, but soon the discovery of gold gave all power to the wealthy; men would not learn how little was needed for happiness; they therefore sacrificed everything for power and eminence. Kings were overthrown and anarchy followed, till nations weary of violence established laws and constitutions; their fear of punishment restrained men, as injustice generally recoils on the wrongdoer and if he escapes punishment he cannot escape the terrors of conscience. Men saw the seasons change and all the wonders of the heaven; they therefore placed their gods in heaven and believed that all things were governed by them.

The metals were discovered through the burning of woods which baked the earth and caused the ore to run. With these they made arms and tools. At first copper was rated more highly than useless gold and silver. For arms, men used at first hands, nails, teeth, clubs, then fire, then copper or brass, at last iron. Horses were first employed in war, then chariots, then elephants—strife begetting one horror after another. Weaving came into use after iron, as the web could not be woven without instruments of iron. Nature first taught to sow, plant, and graft; then one kind of culture after another was devised and more and more ground brought under tillage. Birds taught men song; from the whistling of the zephyrs through reeds they learned to blow through stalks; next the pipe came into use. With such music watchers would while away the time and derive no less pleasure than is now derived from elaborate tunes. Finally came walled towns, division of lands, ships, treaties between states, and, when letters were invented, literature.

Such is the epic of civilization sketched by Lucretius in powerful strokes and such is the complicated state of existence which has arisen as a result of the combination of the simple atom.

The classical atomic theory remained as formulated by Lucretius and rather unfruitful until the sixteenth century when Pierre Gassendi, a French philosopher, revived interest in it. He accepted the theory as outlined, with the exception that, being a churchman, he had God create atoms and void whereas the ancients had them exist from all eternity.

The modern theory of atoms as applied to chemistry was worked out by Dalton at the beginning of the nineteenth century. It is historically the Greek theory with this important difference. The theory of elements had been developed in chemistry and it was to that series of elements that Dalton applied his atomic hypothesis. The original element in his work was the theory that atoms were not of various shapes but that the atoms of different elements were different in weight. From Dalton's time the atomic theory followed two distinct lines of development—one in chemistry and one in physics. Subsequent experiments in physics have led to the isolation of the atom, and one hundred years after the adoption of the atomic theory in its modern form, science demonstrated that the atomic unit is made up of smaller units or electrons. The theory of electrons does not set aside the theory of atoms but goes beyond it.

We are accustomed to view Greece as the mother of all that we have of value in art and literature; is it not, however, somewhat surprising to find such a close connection between this old Greek theory of the constitution of matter and that modern hypothesis which alone permitted the development of the sciences of chemistry and physics? Indeed, we may go so far as to say that none of the ideas of antiquity have been more suggestive than this,[1] for modern scientific research takes its starting-point from the attempt so many centuries ago of Leucippus, the father of the atomists, to reduce qualities to quantities or, rather, to establish fixed relations between the two.

[1] See Gomperz, *Greek Thinkers*, I, 349.